A Study on Hair Removal Characteristics Using a Long-pulsed Alexandrite Laser

Jin-Young Choi*, Sang-Gil Kim*, Jong-Woong Park*, Sung-Joon Park* and Hee-Je Kim†

Abstract - Recently, lasers have become widely used throughout the medical treatment field. Several types of lasers have been used for the purpose of hair removal since the Alexandrite laser was approved by the FDA (Food & Drug Administration) for clinical epilation. In this study, a long-pulsed Alexandrite laser system for hair removal adopting a multi-discharge method in which three flash lamps are turned on consecutively was designed and fabricated. This laser system shows the technology that makes it possible to create extended pulse by turning on three flash lamps consecutively. With this technique, the pulse width can be varied from 4ms~10ms. Then using this Alexandrite laser system with the pulse width 10ms and the beam size 7mm, hair removal was performed on the back portion of a human hand and leg. This study shows that treatment by the long-pulsed Alexandrite laser produces hair removal with no relevant side effects.

Keywords: epilation, hair removal, long-pulsed solid laser, multi-discharge method

1. Introduction

Laser appliances have been widely used in a variety of fields such as material processing, industrial instrumentation, medical equipment, etc. since Maiman first constructed a Ruby laser in 1960 [1, 2].

In particular, the demand and development of laser appliances for medical treatments are gradually increasing because surgical treatments using them are convenient and recovery time is rapid. Several lasers are currently in use for the purpose of hair removal. These include the long-pulsed Ruby (694nm), Nd:YAG (1064nm), diode (810nm), and long-pulsed Alexandrite (755nm) [3].

Long and high energetic pulses lead to thermal destruction of large pigmented cutaneous targets such as the follicle. Melanin within the follicle must be abstracted from the skin in order to remove unwanted hairs. Therefore, the lasers for hair removal must handle wavelengths in the range of 600~1100nm to be selectively absorbed into melanin and to be used for selective photothermolysis [4-6]. The Alexandrite laser is currently in the spotlight. It is highly suitable for hair removal because the 755nm wavelength of Alexandrite penetrates deeply into the dermis and has a lengthy active time. Endogenous melanin-containing cells within the follicle and the hair shaft absorb the 755nm light and are damaged, resulting in a hair removal effect. To decrease the risk of epidermal injury resulting from absorption of the Alexandrite laser light in superficial melanin-containing epidermal cells, the application of a cooling gel is necessary [7-9].

Domestic research efforts on the pulse shaping technique have been focused on output of power supply devices or application rather than the development of power supply devices on the basis of the pulse shape control. As such, it is true that the domestic techniques concerning pulse control parameters are behind those of the advanced nations. Also, the domestic pulse power technique capable of applying the long-pulsed laser for hair removal is not yet established [10, 11].

In this study, we designed and fabricated the long-pulsed Alexandrite laser system adopting a multi-discharge method that can vary the pulse width in accordance with the consecutive turn-on of three flash lamps. And then using our laser system, we studied the hair removal characteristics on the back portion of the human hand and leg.

2. Design

2.1 Laser system unit

Fig. 1 represents a schematic diagram of a laser system unit. There is a circular-type pump cavity in the center of the oscillator and on both sides of the pump cavity. There are two mirrors for laser oscillation: a total reflector (a concave mirror with a reflectivity of over 99.5% and a curvature radius of 2m) and a partial reflector (a plane mirror with a reflectivity of 80%) that constitutes a stable resonator.

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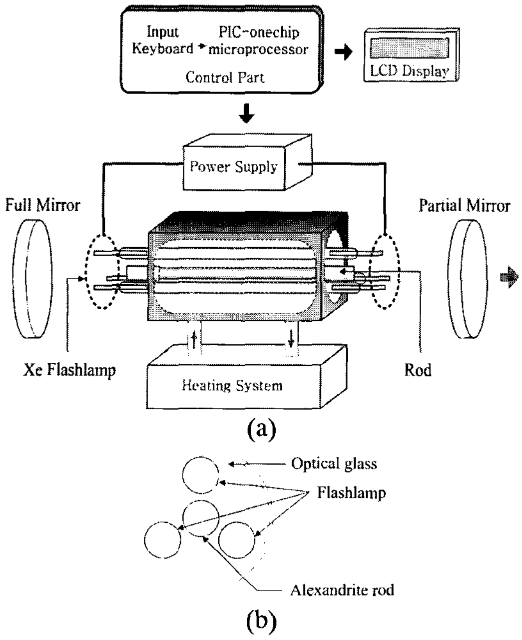


Fig. 1 The Schematic diagram of (a) laser system unit and (b) laser head for multi-discharge method

The pumping cavity was constructed in a round form with the use of optical glass causing a diffused reflection in order to deliver the light radiated from the lamp efficiently to the rod. The pump cavity comprises the rod in the center of the cylindrical cavity and three flash lamps around the rod at an interval of 120°.

2.2 Power supply

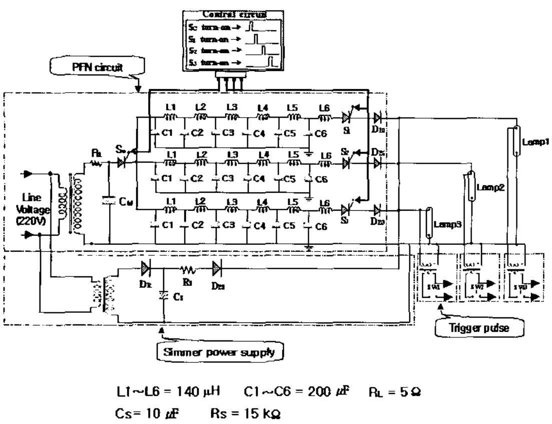


Fig. 2 The long-pulsed Alexandrite laser power supply of a multi-discharge method

Fig. 2 illustrates a long-pulsed Alexandrite laser power supply of a multi-discharge type using the PFN (pulse forming network). It consists of a 6-step mesh to mold the laser output pulse into a rectangular form. In the experiments, the capacitance C, and the inductance L were set at 1200 μF and 840μH, respectively. At this time, the input energy is calculated at 384J (the charging voltage was set at 800V), about 2ms from formulas (1) and (2).

$$E_0 = 1/2\, CV_0^2 \tag{1}$$

$$t_d = 2\sqrt{LC} \tag{2}$$

The operating principle of the above circuit can be summarized as follows:

(1) Authorize DC 1[kV] to both ends of the flashlamp with the simmer power supply, turn on the switch of the trigger pulse circuit and then the streamer discharge is sustained in the flashlamp.

(2) When SCR Sc is turned on, the energy is charged in the capacitance of the PFN, and then SCR S1, S2 and S3 are turned on consecutively. At this time, the energy stored in the capacitance of the PFN is delivered and the lamp is turned on.

2.3 Control Circuit

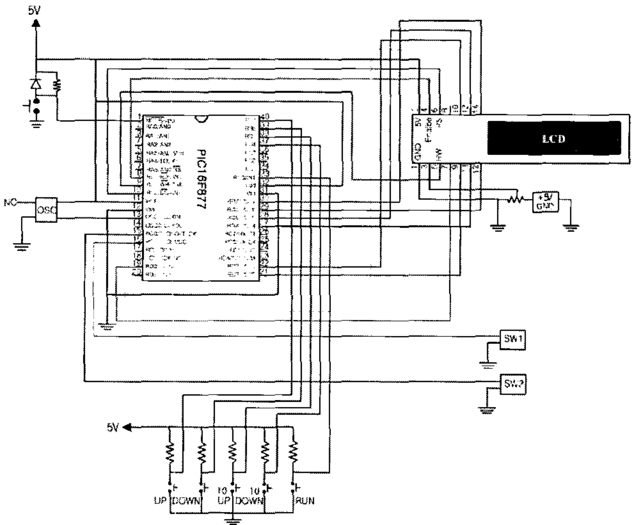


Fig. 3 PIC16F877 control circuit

Fig. 3 represents the turn-on delay time control circuit of the SCR comprising a PIC one-chip microprocessor. This control circuit consists of four parts: the keyboard that enters the delay time; the multi-segmented LCD displays; the PIC one-chip microprocessor, which is the most key part of the control circuit; and the amplification circuit to turn on the SCR.

In this control circuit, the delay time information is entered by the keyboard, and this input is conveyed to the PIC, which in turn outputs four different signals in accordance with the predetermined program. But these signals are too weak to turn on the SCR and therefore the current and voltage are amplified with use of a transistor for high-speed switching. These amplified signals first turn on SCR

Sc and then turn on SCR S1, S2 and S3 consecutively with a precision of up to 1 μs.

3. Experimental results

In this study, we designed and fabricated a long-pulsed Alexandrite laser system adopting the multi-discharge method with the pulse width of 10ms to assist with our experiment on hair removal characteristics. At first, we accomplished the fundamental lasing experiment with the Alexandrite laser system and then experimented in earnest with the long-pulsed Alexandrite laser system adopting a multi-discharge method.

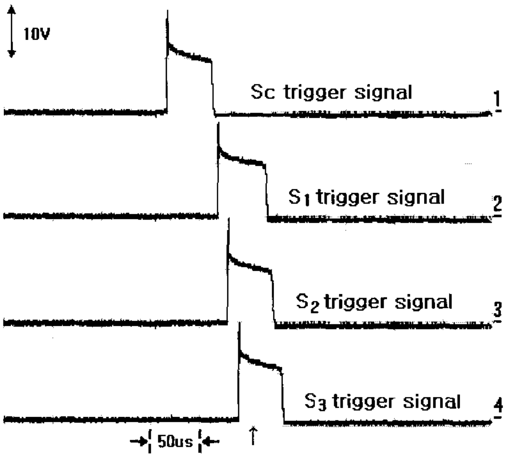


Fig. 4 Gate trigger signals of SCR using PIC one-chip microprocessor

Fig. 4 indicates the gate trigger signals of SCR using a PIC one-chip microprocessor. Signal 1 is triggered after SCR Sc is triggered and signals 1, 2 and 3 are triggered at a certain delay time interval by 10 μs, turning on SCRs consecutively.

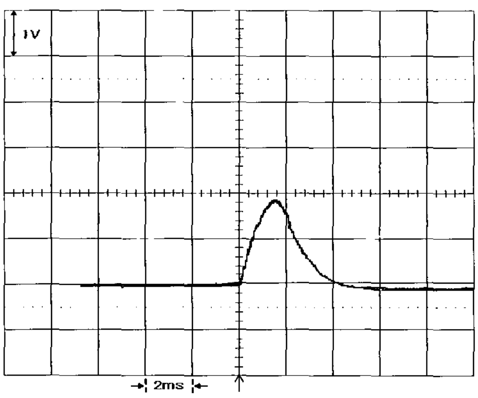


Fig. 5 The laser temporal beam profile when a single flashlamp is turned on

The temporal laser profile when a single flashlamp is turned on is shown in Fig. 5. At this time, the FWHM (full width at half maximum) is approximately 2ms.
All waveforms were measured with a pulse current transformer (Pearson Electronics Co.), having a sensitivity of 0.001A/V. Therefore, the peak current in Fig. 5 was 2000A.

This waveform was obtained when the input energy was 384[J] and the output energy of the laser was approximately 1 [J]. This is identical to the temporal laser beam profile of the flashlamp.

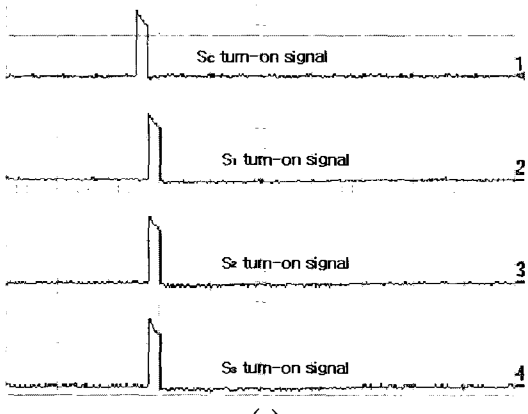
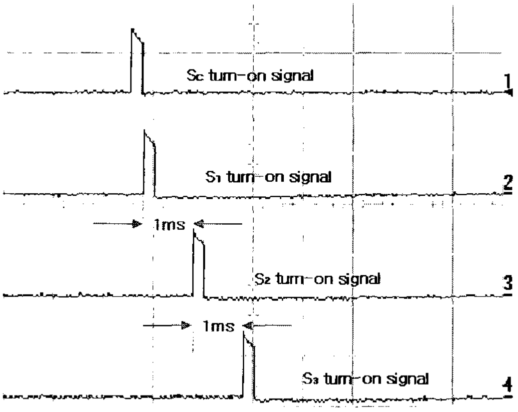
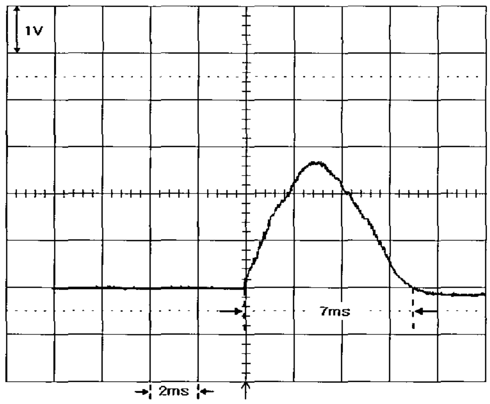


Fig. 6 (a) Gate trigger signals of SCR and (b) temporal laser beam profile when the delay time is set at (0ms, 0ms).

Fig. 6 (a) depicts the gate trigger signals of SCR and Fig. 6 (b) shows the temporal laser beam profile when the delay time is set at 0ms (when the lamps are turned on simultaneously). At this time, the FWHM is about 2ms and the peak value is about 2.6 times greater than that of a single flashlamp. In this case, the typical temporal laser beam profile was obtained from a multi-pulse superposition technique stemmed from a two-pulse superposition technique [12-14].



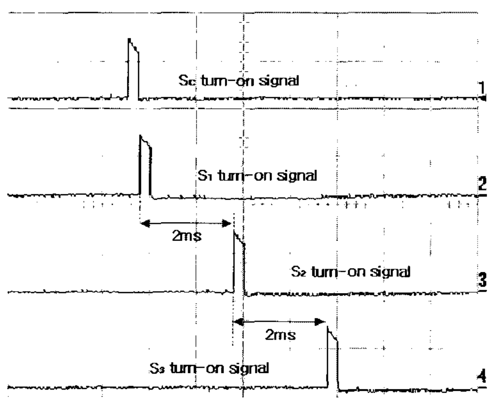
(a)



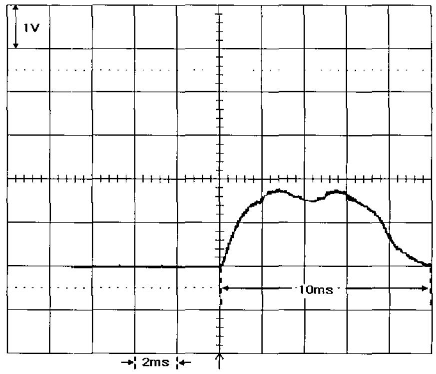
(b)

Fig. 7 (a) Gate trigger signals of SCR and (b) temporal laser beam profile when the delay time is set at (1ms, 1ms).

Fig. 7-(a) presents the gate trigger signals of SCR and Fig. 7-(b) shows the temporal laser beam profile when the delay time interval is set at 1ms. Here, the pulse width stands at about 7ms and the peak value is about 1.5 times greater than that of a single flashlamp. The typical temporal laser profile was generated in a step-like waveform caused by adjusting the delay time of each SCR consecutively.



(a)



(b)

Fig. 8 (a) Gate trigger signals of SCR and (b) temporal laser beam profile when the delay time is set at (2ms, 2ms).

Fig. 8 represents the gate trigger signal of SCR and the temporal laser profile when the delay time is set at 2ms. In this case, the pulse width is about 10ms. This generated waveform was nearly the same as one caused in the above mentioned case.

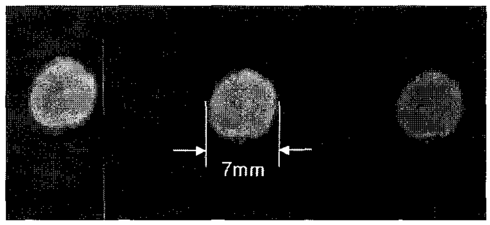
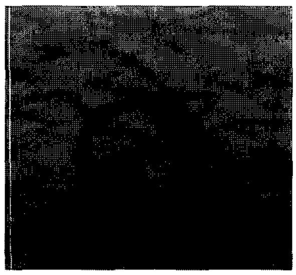
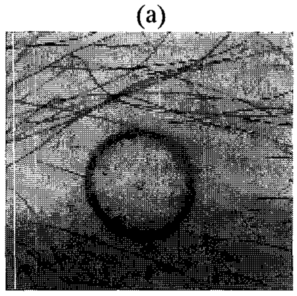


Photo 1 Beam size of the Alexandrite laser

Photograph 1 shows the beam size of the Alexandrite laser taken using photosensitive paper. The beam size is about 7mm.



(a)

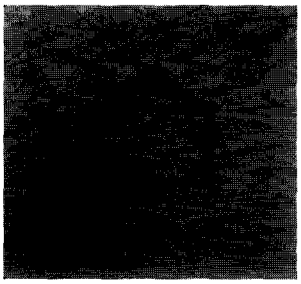


(b)

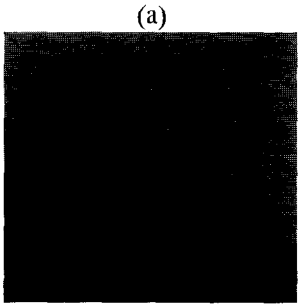
(c)

Photo 2 Hair removal performed on a part of the leg using the Alexandrite laser (a) before treatment (b) after shaving (c) 1 month after treatment

Photograph 2 shows the removal of unwanted hair on a part of the leg by way of our long-pulsed Alexandrite laser system with a pulse width of about 10ms and beam size of about 7mm. The part designated in red is the target. The region size is approximately 1cm in diameter, considering that the beam size is about 7mm. Photographs were obtained before treatment, after shaving the region immediately before treatment and 1 month postoperatively. The unwanted hair in the designated region was clearly removed without hair regrowth.



(a)



(b)

Photo 3 Hair removal performed on the back portion of the hand using Alexandrite laser (a) before treatment (b) one month after treatment

The hair removal performed on the back portion of the hand using our long-pulsed Alexandrite laser is represented in Photograph 3. The region designated in red is the local portion about 1 cm in diameter. Photograph 3 (a) shows the target before treatment and we are able to observe that the majority of hairs were removed in photo 3 (b), which shows the specimen at 1 month postoperative.

4. Conclusion

In this study, we proposed a long-pulsed Alexandrite laser system adopting a multi-discharge method utilizing each SCR gate with an adjusting delay time by a PIC one-chip microprocessor. Using this system, we studied the hair removal characteristics.

In a result, the peak value of the laser pulse output in accordance with the turn-on delay time of the flashlamps is approximately 1~2.6 times greater than that of a single flashlamp, and the pulse width can be controlled at about 4~10ms when the three lamps are consecutively turned on at the delay time interval of 0, 1 and 2 ms. Using the long-pulsed Alexandrite laser system of the multi-discharge method with the pulse width of 10ms and the beam size of 7mm, we performed the removal of unwanted hair on the back portion of a hand and leg. We also confirmed the hair removal effect using our laser system.

Acknowledgements

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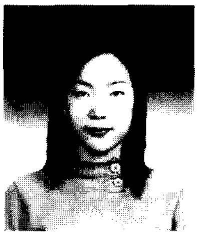

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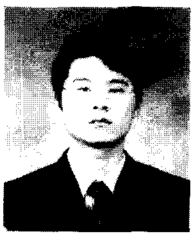

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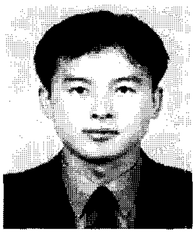

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